Thermal-elastic modelling of a complex system. Succesfully combining different modelling techniques

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Abstract

In high-precision systems, thermal effects have a large influence on system performance, regarding accuracy, throughput and reliability. Especially under extreme conditions (for example, vacuum or cryogenic) with high heat loads. It is crucial to give this aspect sufficient attention in the design phase. Predictive modelling shows the impact of design choices in an early stage, and provides objective feedback for system or component design.

The thermal-elastic modelling of high-precision systems typically consists of hand calculations, lumped mass models and FEM models. Lumped mass models and FEM models both have their (dis)advantages. An example of a complex thermal-elastic system model of an Transmission Electron Microscope (TEM) will be shown. The system is complex in the sense of the high number of parts and interfaces and the physical (thermal and elastic) interaction between the parts. The overall thermal system model is based upon the lumped mass approach, and is coupled to a 1D elastic lumped mass system model. The model consists of approximately 100 thermal masses (nodes). Managing such a large models and be able to redefine and change the model and performing post-processing efficiently is a known challenge. This is solved by the use of an in-house developed toolbox in MATLAB [1]. The estimation of the thermal properties of the elements in the lumped mass system model is partly done by detailed FEM analyses of the system components. The successful combination of these modelling techniques to establish the overall system model of the complex TEM model will be explained by means of examples.

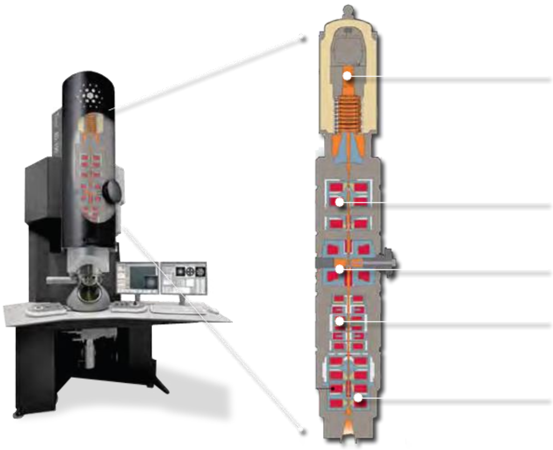

Figure 1: Transmission Electron Microscope (TEM): system overview

[1] J.C.G. van der Sanden, T.A.M. Ruijl, “Thermal transient analysis of complex systems using structured lumped mass models”, Philips Applied Technologies, The Netherlands, Proceedings of the Topical Meeting: Thermal Effects in Precision Systems – Maastricht- December 2007, pp 32 – 35.